Air Cooled Absorption for Power Applications

Course Number: ME-02-500

PDH: 5

Approved for: AK, AL, AR, DE, FL, GA, IA, IL, IN, KS, KY, LA, MD, ME, MI, MN, MO, MS, MT, NC, ND, NE, NH, NJ, NM, NV, NY, OH, OK, OR, PA, SC, SD, TN, TX, UT, VA, VT, WI, WV, and WY

State Board Approvals

Florida Provider # 0009553 License #868
Indiana Continuing Education Provider #CE21800088
Maryland Approved Provider of Continuing Professional Competency
New Jersey Professional Competency Approval #24GP00025600
North Carolina Approved Sponsor #S-0695
NYSED Sponsor #274

How Our Written Courses Work

This document is the course text. You may review this material at your leisure before or after you purchase the course.
After the course has been purchased, review the technical material and then complete the quiz at your convenience.
A Certificate of Completion is available once you pass the exam (70% or greater).
If a passing grade is not obtained, you may take the quiz as many times as necessary until a passing grade is obtained).
If you have any questions or technical difficulties, please call (508) 298-4787 or email us at admin@PDH Pro.com.

1.0 Introduction/Background

Combined Heat and Power (CHP) systems are widely used in the U.S. in industrial and institutional applications, but are relatively uncommon in commercial-building applications. The DOE Distributed Energy Program is extending CHP to commercial-building applications through the combination of technology development partnerships with industry, and education and information dissemination activities. DOE recognizes the economic and energy-saving benefits of using available heat to provide space cooling through the use of absorption chillers, and is promoting the development and deployment of related technologies. One key market barrier to the use of absorption chillers in light-commercial CHP systems is the need for a cooling tower to reject heat from the condenser and the absorber to the ambient. The use of cooling towers is unpopular in light-commercial applications because cooling towers:

- Can provide breeding grounds for Legionella, the bacteria that cause Legionnaires' disease;
- Increase first costs significantly;
- Require regular maintenance; and
- Require significant physical space.

The development of air-cooled absorption chiller technology could address most of these issues by eliminating the need for a cooling tower.

The objective of our investigation is to summarize the development status of air-cooled lithium bromide (LiBr)-water absorption chillers to guide future efforts to develop chillers for CHP applications in light-commercial buildings (typically 10 to 150 RT). Unfortunately, absorption systems have proven particularly difficult to evaluate analytically with any degree of confidence due to the complex interactions of heat and mass transfer and the number of components involved. While much analytical work suggests that air-cooled LiBr systems are technically and economically feasible, we focused primarily on seeking laboratory and/or field demonstrations of performance and cost-effectiveness.

There are alternatives to LiBr-water absorption that we did not consider, including:

- Ammonia-water absorption (or other refrigerant/sorbent pairs[1]);
- Adsorption/chemisorption; and
- Rankine-cycle devices that use waste heat to generate shaft power that, in turn, drives vapor-compression cooling equipment.

These alternatives were simply outside the scope of our investigation. They may very well warrant analysis for CHP applications.

[1] We made one exception by including a metal hydroxide solution developed by Energy Concepts that does not contain LiBr.

There is another approach to eliminating cooling towers for LiBr absorption chillers that we did not consider—ground-coupled heat rejection. This technically sound approach is currently under investigation by other researchers[2] so we did not duplicate efforts.

Our investigation focused on the air-cooling aspects of the CHP application, rather than the operation of absorption equipment on waste-heat streams. While consideration of the latter is important, approaches to using waste-heat streams appear to be well understood, as at least two major manufacturers (United Technologies and Broad) have commercialized CHP absorption products/systems (using cooling towers).

Foley, et al [21] provides an excellent starting point for this investigation, having reviewed and summarized development work that took place in the 1980's and 1990's. Foley's key observations include:

- The main technical hurdle to air-cooled absorption cooling is the crystallization limit in the absorber;
- Two approaches have been used—mechanical (i.e., improved heat exchangers) and chemical (i.e., additives that shift the crystallization curve);
- Asian manufacturers developed products suitable for moderate climates based primarily on the mechanical approach, but these products are not suitable for U.S. climate conditions; and
- Carrier, in their DOE-funded efforts to develop a solar-fired absorption chiller, developed a solution called Carrol that is suitable for temperature ranges experienced in single- effect absorption machines.

[2] Researchers at Oak Ridge National Laboratory are investigating ground-coupled heat rejection for LiBr absorption [16].

2.0 LiBr Absorption Overview

Figure 1 illustrates the basic single-effect LiBr-water absorption cycle. The absorber/pump/solution heat exchanger/generator assembly essentially replaces the compressor in a vapor-compression refrigeration system. This assembly is sometimes referred to as a thermal compressor. A dilute (weak) solution of LiBr in water is pumped from the absorber to the generator. A solution heat exchanger preheats the weak solution before entering the generator. Heat is added to the generator to boil the water (the refrigerant) from the solution.
The water vapor then flows to the condenser, where it is condensed and heat is rejected to the ambient. The condensed water flows through an expansion device, where the pressure is reduced. The heat flows into the evaporator (providing the desired cooling effect) to evaporate the water. The water vapor then returns to the absorber.

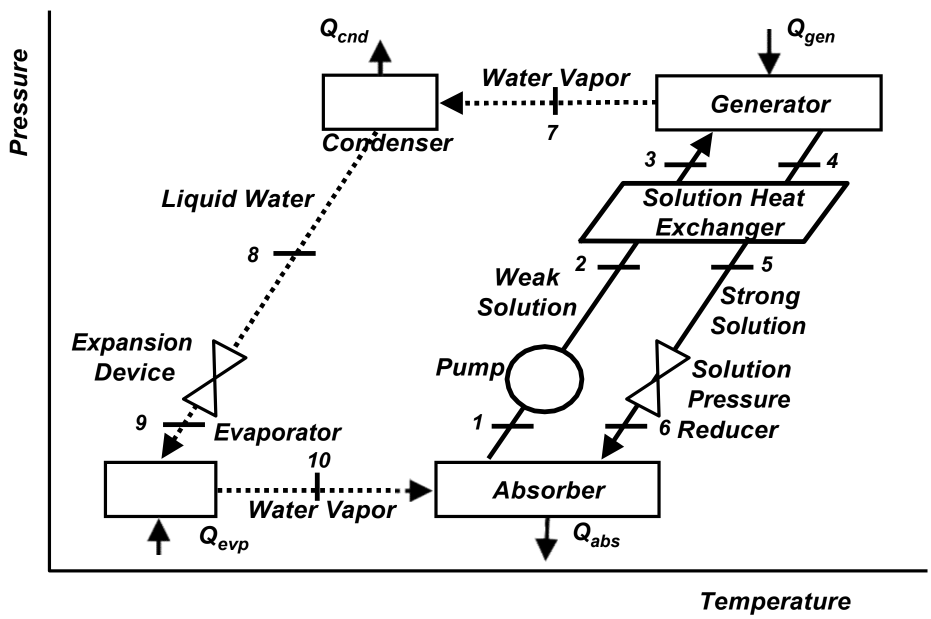


Figure 1: Basic Single-Effect LiBr Absorption Cycle

When the water is boiled out of the weak solution in the generator, the remaining solution becomes strong (high concentration of LiBr). The strong solution is cooled in the solution heat exchanger, flows through a flow restriction to lower its pressure, and returns to the absorber.
The strong solution in the absorber absorbs the water vapor returning from the evaporator, diluting the solution. Since the water vapor is now liquid water, this process releases the heat of vaporization, which must be rejected. The entire cycle operates below atmospheric pressure.

In a direct-fired, water-cooled absorption chiller, heat is supplied to the generator from combustion of fossil fuel and cooling water takes the heat rejected by the absorber and condenser to a cooling tower for rejection to the ambient air. In a CHP application, waste heat from the prime mover is supplied to the generator. There are two options for air cooling of an absorption chiller:

1. Use a conventional, water-cooled condenser and absorber, and substitute a dry coil for the cooling tower to reject heat to the ambient air; or
2. Replace the condenser and absorber with an air-cooled condenser and air-cooled absorber.

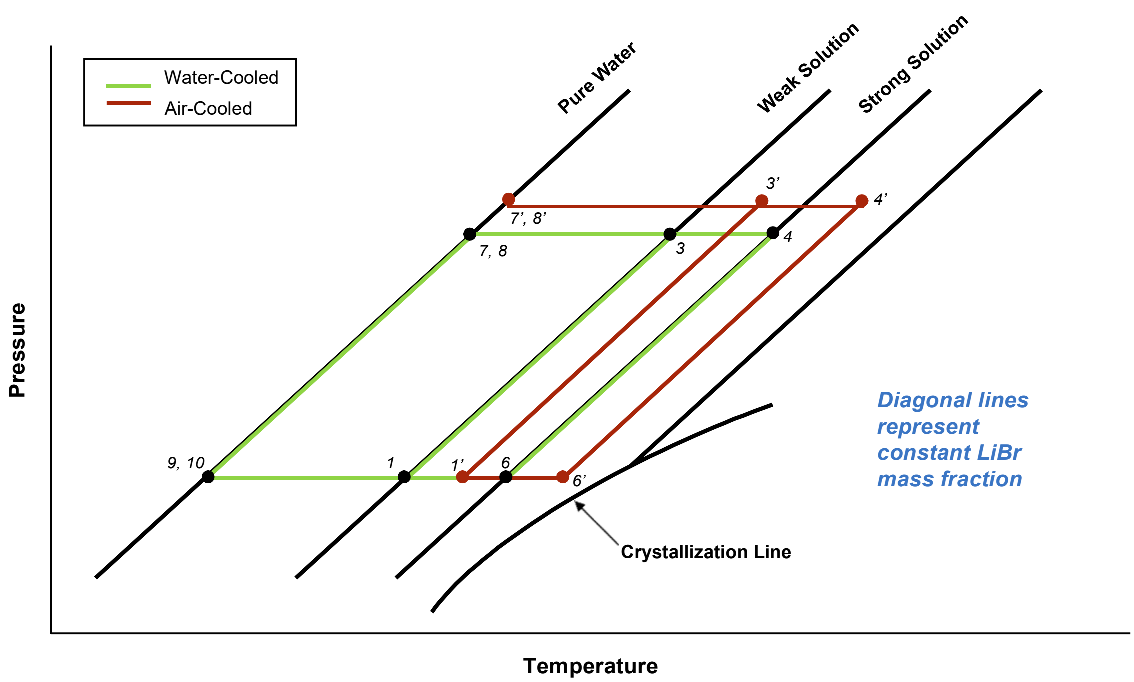
3.0 Key Technology Barriers

As characterized by previous investigators such as Foley, et al [21] and Kurosawa, et al [30], the key barrier to air cooling of LiBr chillers in U.S. climates is crystallization of LiBr in the absorber. Table 1 lists typical temperature and LiBr concentration limits for the absorber to avoid crystallization. Figure 2 compares (using Dühring diagrams) the temperature/pressure/concentration characteristics of a typical water-cooled chiller to those for an air-cooled chiller. The figure illustrates that the higher heat-rejection temperatures associated with air cooling bring the cycle closer to the crystallization curve, increasing the possibility of crystallization, especially during transients.

Table 1: Absorber Temperature and Concentration Limits to Avoid Crystallization[a]

Chiller Type	Absorber Temperature Limit, °F	Strong Solution Concentration, % by Weight
Single Effect[b]	Approx. 129°F	61 to 64%
Double Effect[c]	Approx. 129°F	64%

a) For an evaporator condition of 40°F/0.127 psia.
b) From Liao [31]
c) From Izquierdo [26]



See Figure 1 for definition of state points.
Adapted from Figure 20, ASHRAE Fundamentals Handbook [1].

Figure 2: Dühring Diagram Comparing Air-Cooled and Water-Cooled Single-Effect Absorption